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SPACE SHUTTLE/ FOOD SYSTEM STUDY

FINAL REPORT

PACKAGE FEASIBILITY STUDY

CONTRACT NAS 9-13138

MODIFICATIONS 3S, 4C and 5S

prepared for

NATIONAL AERONAUTICS and SPACE ADMINISTRATION

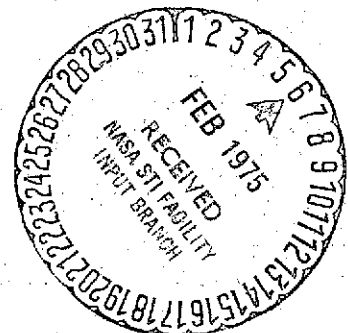
Manned Spacecraft Center
Houston, Texas 77058

Contract NAS9-13138

Prepared by



THE PILLSBURY CO.



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INDEX

| <u>Section</u> | <u>Title</u> | <u>Page</u> |
|----------------|--------------------------------------|-------------|
| 1.0 | Introduction | 1 |
| 1.1 | Study Goals | 1 |
| 1.2 | Approach | 1 |
| 1.2.1 | Alternate Concepts | 1 |
| 1.2.2 | Optimum Concept | 2 |
| 1.2.3 | Rehydratable Package Development | 2 |
| 1.2.4 | Drink Package Concept | 3 |
| 1.2.5 | Drink Cup Concept | 3 |
| 1.3 | Rehydratable Package Detailed Design | 3 |
| 1.3.1 | Design Criteria | 3 |
| 1.3.2 | Alternate Design Configurations | 3 |
| | Design Configuration A | 4 |
| | Design Configuration B | 4 |
| | Design Configuration C | 4 |
| | Design Configuration D | 4 |
| | Design Configuration E | 12 |
| 1.3.3 | Design Selection | 12 |
| | Design Configuration A | 16 |
| | Design Configuration B | 17 |

| <u>Section</u> | <u>Title</u> | <u>Page</u> |
|----------------|------------------------|-------------|
| | Design Configuration C | 17 |
| | Design Configuration D | 18 |
| | Design Configuration E | 18 |
| 1.3.4 | Fluid Seal | 19 |
| 1.3.4.1 | Materials | 19 |
| 1.3.4.2 | Fluid Seal Location | 20 |
| 1.3.4.3 | Needle Design | 20 |
| 1.3.4.4 | Rehydration | 25 |
| 1.4 | Drink Package Concept | 36 |

1.0 INTRODUCTION

At the conclusion of the Space Shuttle Food System Study The Pillsbury Company and Fairchild Republic Corporation presented what was considered to be a optimum feeding system for the Space Shuttle. This system consisted of all rehydratable type foods which were enclosed in a 4" x 4" x 1" flexible package. Since this flexible package was a concept, it was recognized by the NASA that a feasibility follow on study was required. This feasibility follow on study has been completed and this section includes the results of this effort, and presents two acceptable, feasible prototypes for this package.

1.1 Study Goals

The goals of the work in support of this study were twofold:

1. Design and development of one or more functional prototypes of the rehydratable package.
2. Describe a drink package concept which would be compatible with the water dispensing device used with the rehydratable package.
3. Present a drink cup concept to be used in conjunction with the water dispensing system.

1.2 Approach

1.2.1 Alternate Concepts

Alternate concepts were generated and subjected to tradeoff analysis in the System Design Study of NAS 9-13138. The concepts considered were as reported in Volume II, Appendix 8, Section 3.3.4.2 of the

1.2.1 Alternate Concepts (cont'd)

final report of that portion of the study.

1.2.2 Optimum Concept

The trade off analyses conducted during the original System Design Study of NAS 9-13138 identified a square package of the configuration 4" x 4" x 1" as being optimum due to its stowage efficiency and maximum use potential. This concept was selected for further work in a laboratory in developing a series of methods for incorporating the rigid base with the flexible top. This basic design concept resulted in five basic design configurations.

1.2.3 Rehydratable Package Development

For the purpose of the concept development effort it was necessary to define functionality as it applied to the finished prototypes. This definition includes the following:

- a) Consideration of manufacture
- b) Stowage
- c) Rehydration
- d) Consumption
- e) Reclosure
- f) Waste disposal.

Several alternative design configurations have been produced and evaluated. Two feasible design configurations were identified, prototypes developed, and presented to the NASA for their evaluation.

1.2.3 Rehydratable Package Development (cont'd)

To support the final designs of the packages selected, sufficient ancillary rehydration studies were conducted to assure package feasibility.

1.2.4 Drink Package Concept

Based on the existing Apollo package which was modified to accept the needle and septum, a drink package has been presented. This package concept is compatible with the rehydration hardware proposed for the Shuttle Galley.

1.2.5 Drink Cup Concept

A reusable drink cup concept was presented which utilizes a disposable liner.

1.3 Rehydratable Package Detailed Design

1.3.1 Design Criteria

The design criteria of the rehydratable package were determined in the initial System Design Study. These are:

- a) 4" x 4" square configuration
- b) Average fill height; approximately 1.03" (flexible)
- c) Semi-rigid package base
- d) Capable of maintaining internal vacuum during storage
- e) Reclosable for waste disposal.

1.3.2 Alternate Design Configurations

Five alternative configurations were generated consistent with the general concept parameters identified in paragraph 1.3.1. These are described below:

1.3.2 Alternate Design Configurations (cont'd)

Design Configuration A

This configuration consists of a semi-rigid base illustrated in Figure 1, and a flexible tubular top illustrated in Figure 2.

The package is formed by inserting the walls of the base into the flexible top and effecting a heat seal at the juncture of the two components. Figure 3 shows the assembly of the entire package.

Design Configuration B

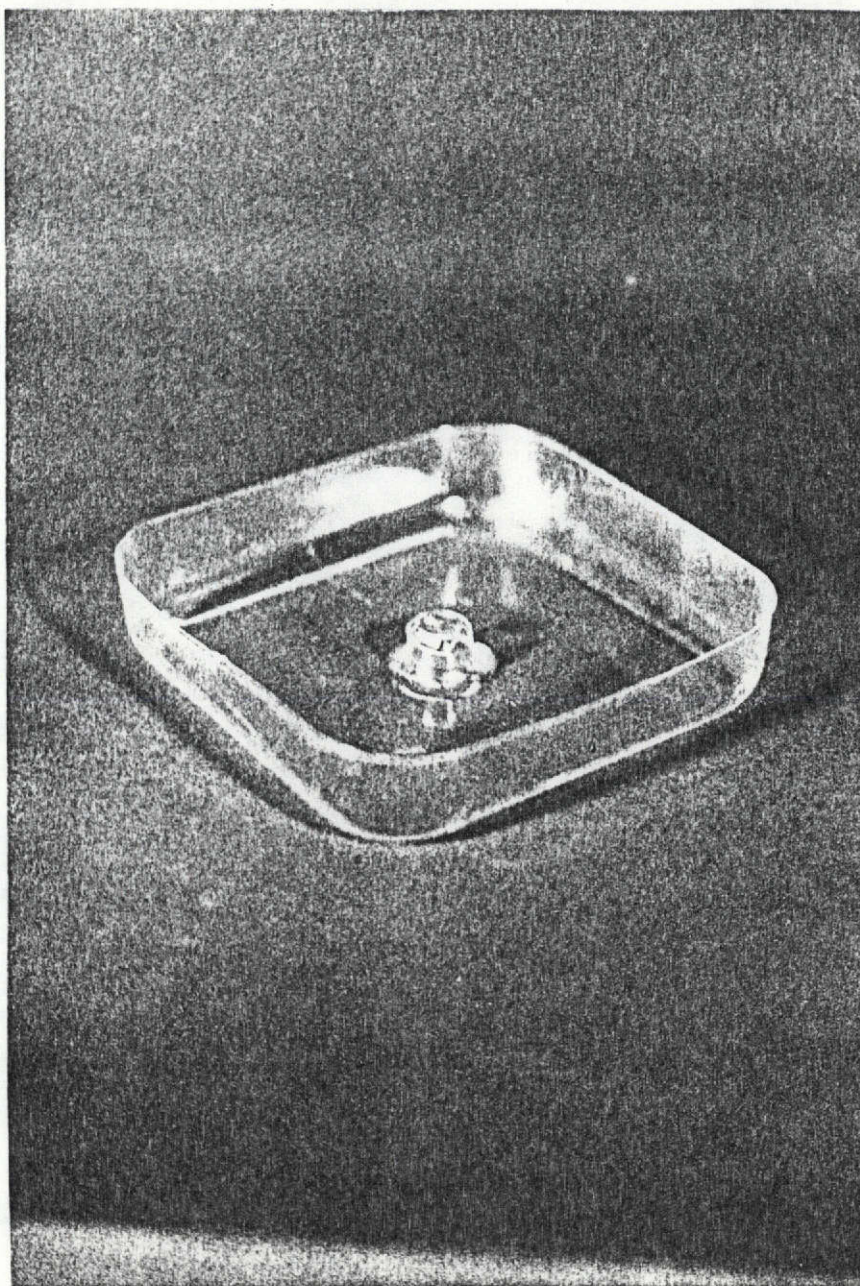
This package consists of semi-rigid base and a tubular flexible top which is closed at one end by gusset seals as shown in Figure 4. The package is formed by inserting the base into the flexible top and heat sealing the two components over the entire surface of the base. Figure 5 shows the package assembly.

Design Configuration C

This package also consists of a semi-rigid base and a tubular flexible top which is closed at one end by a seal in the form of an H as shown in Figure 6. Figure 7 shows the completed assembly of this package.

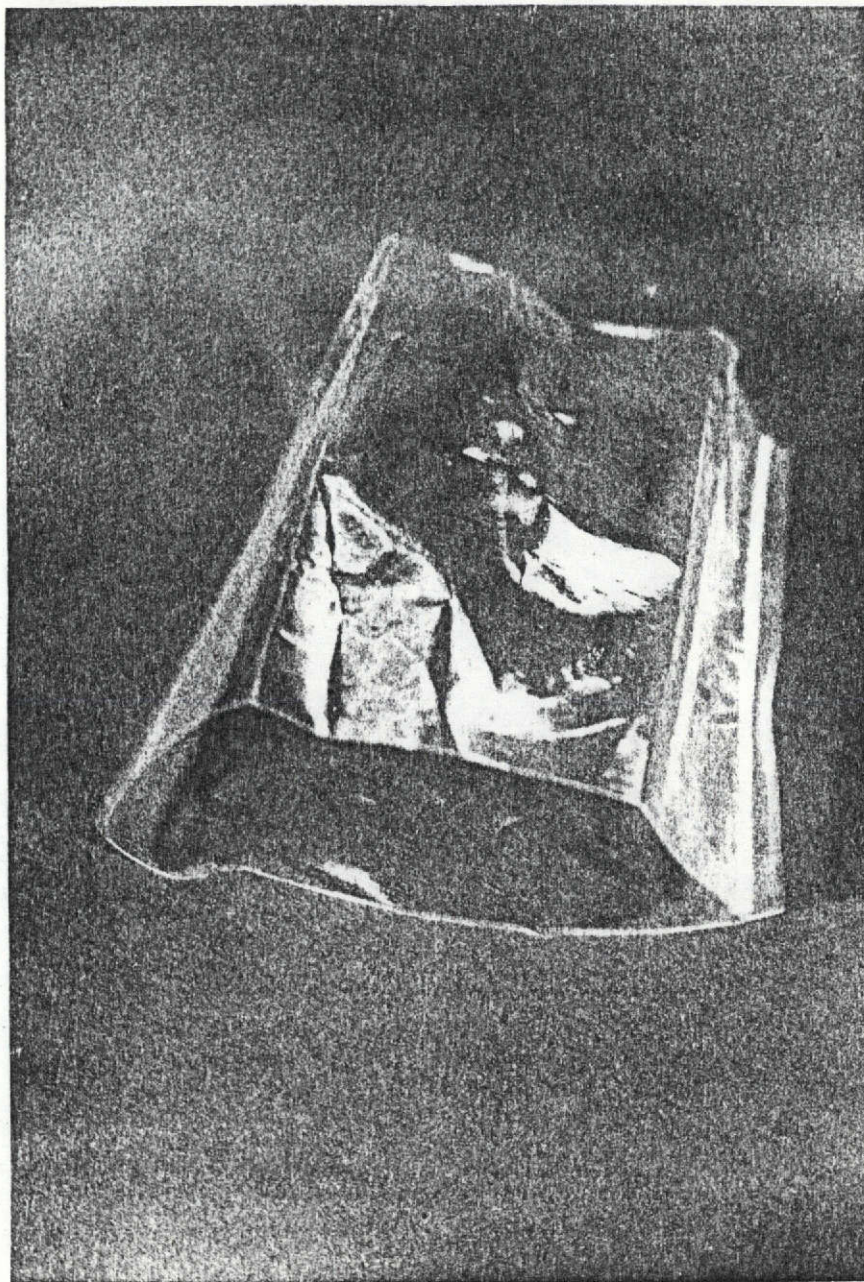
Design Configuration D

This package consists of a semi-rigid base and a tubular flexible top closed at one end with heat seals in an H pattern. The package is assembled by inserting the closed end of the top into the cavity



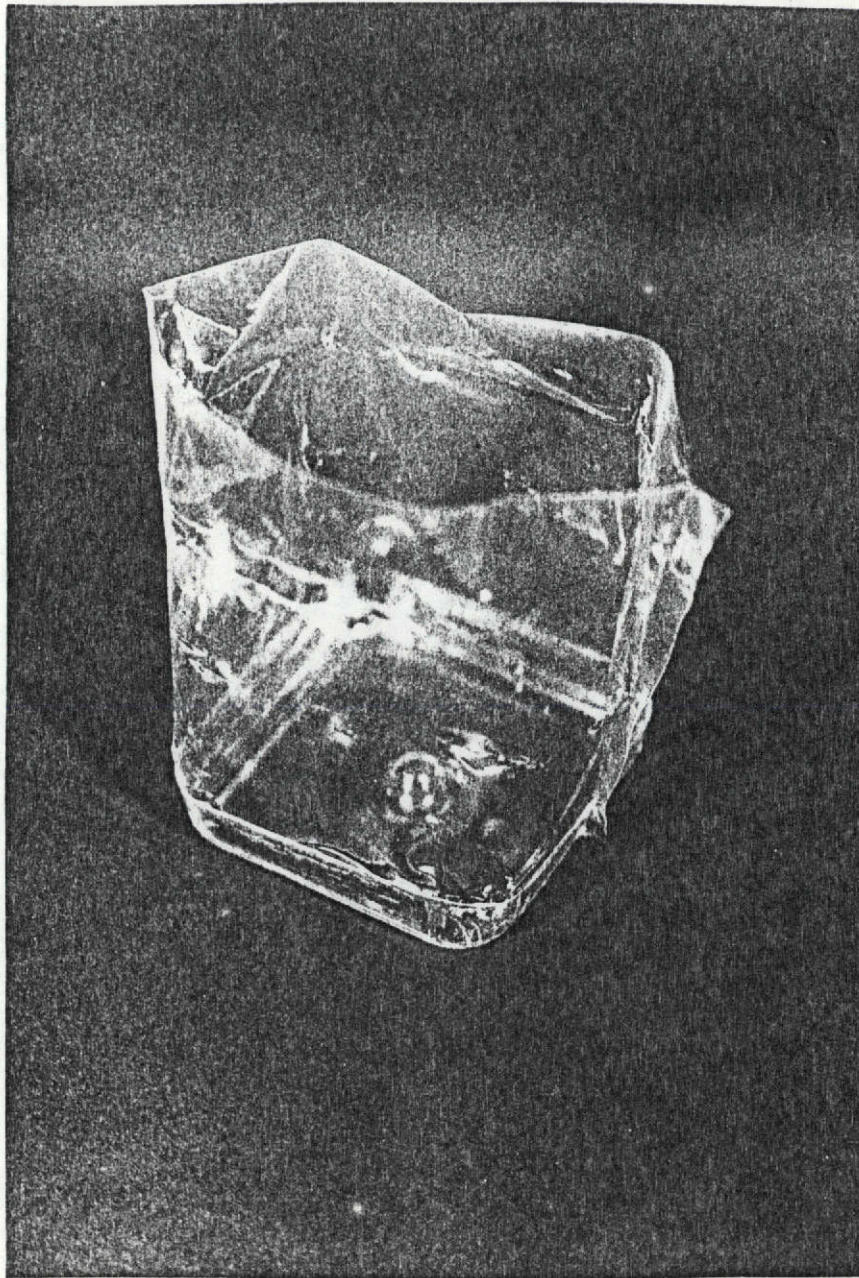
SEMI-RIGID BASE

FIGURE 1



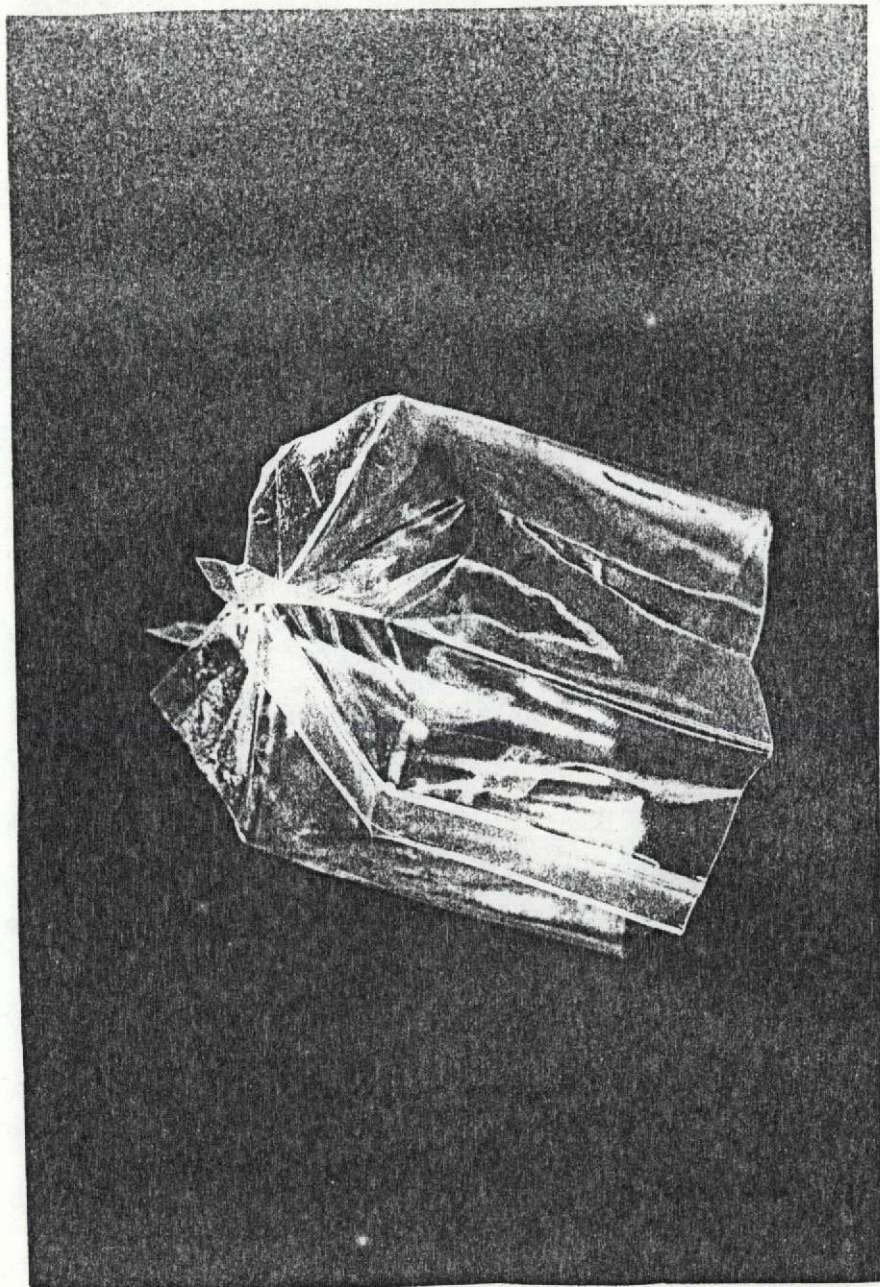
FLEXIBLE SLEEVE

FIGURE 2



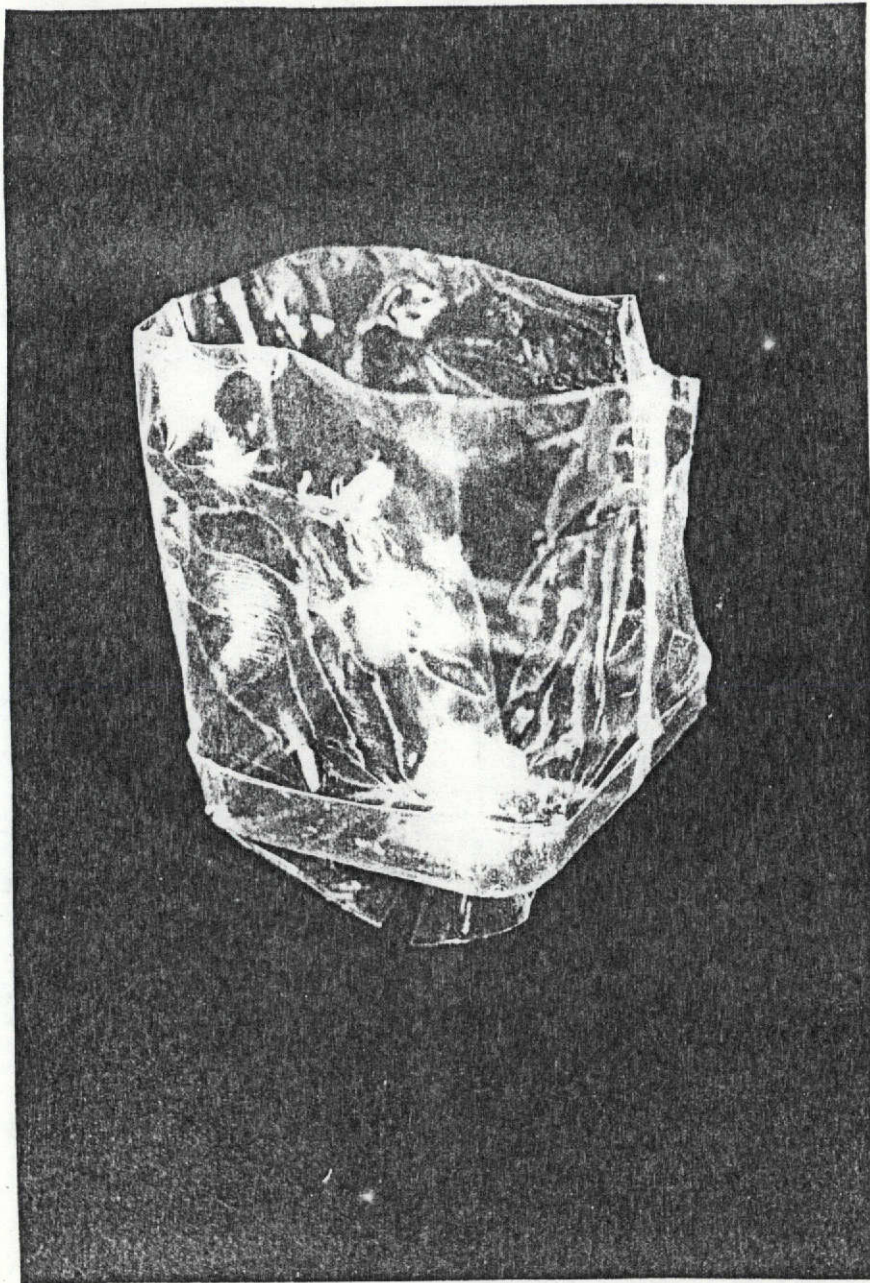
ASSEMBLY - DESIGN CONFIGURATION A

FIGURE 3



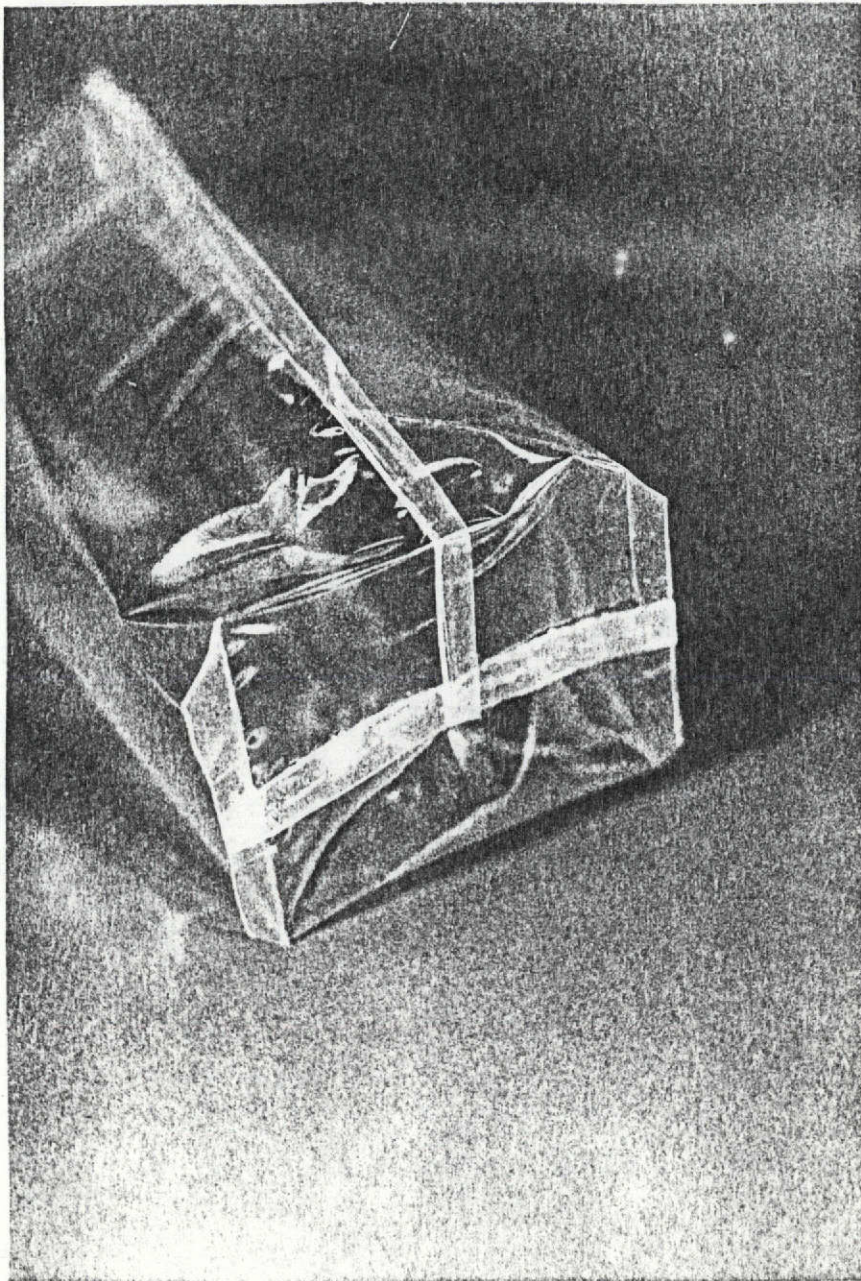
GUSSET SLEEVE

FIGURE 4



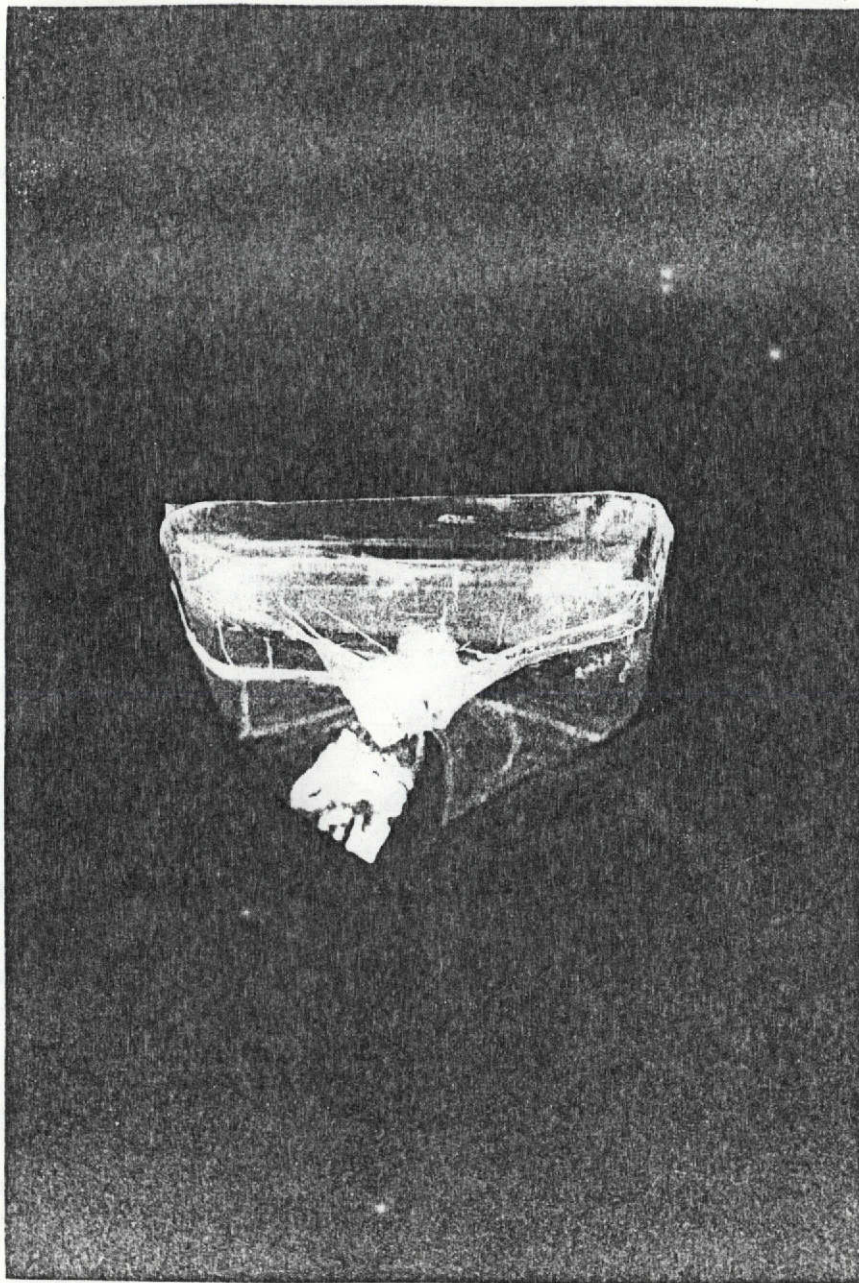
ASSEMBLY - DESIGN CONFIGURATION B

FIGURE 5



'H' SEAL SLEEVE

FIGURE 6



ASSEMBLY - DESIGN CONFIGURATION C

FIGURE 7

1.3.2 Alternate Design Configurations (cont'd)

of the base as shown in Figure 8. Attachment to the base is effected by either heat seals or adhesives.

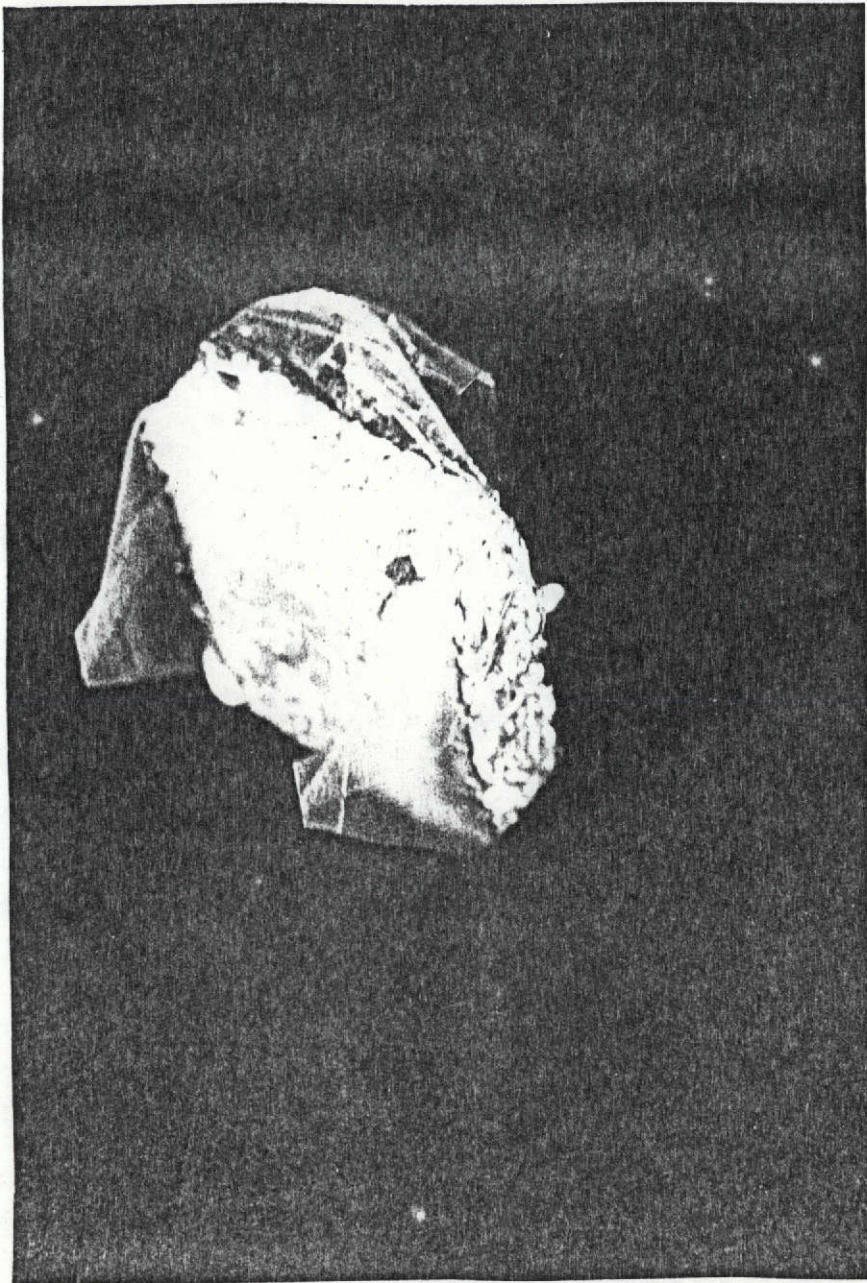
Design Configuration E

This package consists of semi-rigid base and a tubular flexible top closed at one end with heat seals in an H pattern. For this package the gussets or "ears" which are formed during manufacture of the flexible top are allowed to remain, as shown in Figure 9. Assembly of the package is effected by inserting these "ears" into slits cut along opposite walls of the base as shown in Figure 10. The "ears" are then glued, heat sealed or taped along the bottom of the base.

1.3.3 Design Selection

Each of the alternative design configurations was evaluated according to the following criteria:

- a) ease of manufacture
- b) stowability
- c) reliability
- d) available materials
- e) rehydration
- f) consumption
- g) reclosure



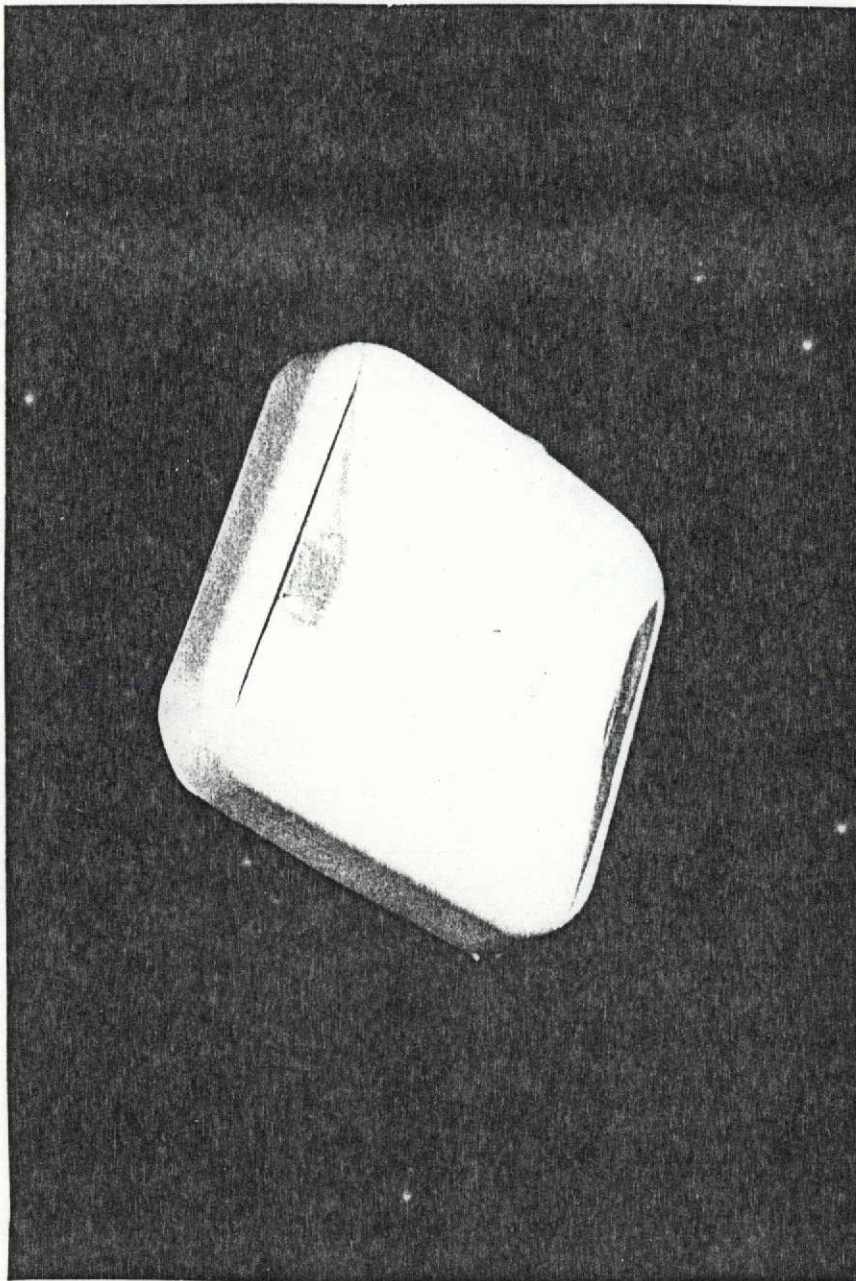
ASSEMBLY - DESIGN CONFIGURATION D

FIGURE 8



ASSEMBLY - DESIGN CONFIGURATION E

FIGURE 9



ASSEMBLY - DESIGN CONFIGURATION E

FIGURE 10

1.3.3 Design Selection (cont'd)

Design Configuration A

To allow for efficient on-board stowage, extended product shelf life, and efficient and complete rehydration, a criterion has been established for the package to maintain an internal pressure of 1.0 psia during its entire shelf life.

Monomeric packaging material by their very nature are not capable of providing the necessary barrier properties to insure maintenance of internal vacuum. Because of this, other laminated packaging materials will be required to provide the necessary barrier properties. To manufacture a package of Design Configuration A it is necessary that monomeric materials be utilized. The base can be formed by many methods but the best observed method is that it be constructed by vacuum forming which by the existing state of the art will not accomodate laminates. Seamless flexible tubing of the kind necessary to effect this design is currently beyond the state of the art, however, within the Shuttle time frame the state of the art should be advanced to the point where manufacture of these flexible seamless tubes will be possible. A flexible tube constructed of laminate by a fin seal results in a three surface heat seal when joined to the base introducing a point of unreliability. Additionally, the currently available materials of which the base could be constructed introduces compatibility problems with the food. This has the potential of creating off-flavors and odors.

1.3.3 Design Selection (cont'd)

Design Configuration B

The tubular flexible top in this design can be easily constructed from a web of laminate material although it would likely be partially a hand operation. Additionally, since the base is contained with the flexible material, monomeric material can be used for the base without regard for barrier properties. This arrangement does not, however, avoid the compatibility problems of the base with the food product as in Design Configuration A.

The gusset seals at the base of the assembled package are somewhat bulky, restricting the available locations for the fluid seal. This excess bulk affects efficient stowage.

This design configuration results in considerable distortion of the base when the food is vacuum packed, especially when the package is only partially filled. The distorted base has a tendency to form sharp corners with the capability of puncturing the film. The use of thicker base materials reduces this tendency but increases package weight.

Design Configuration C

This package is identical to Design Configuration B, except that the bottom seals are formed in an H pattern, creating a less bulky package. This design permits more options for fluid seal locations. This configuration is more easily assembled than Design Configuration B.

1.3.3 Design Selection (cont'd)

Design Configuration D

This configuration eliminates compatibility problems by placing the base outside of the flexible package, where it will not be in contact with the food.

With this design, a serious source of failure is eliminated.

Because the flexible package is located within the semi-rigid base in this design configuration, distortion of the base due to internal vacuum is significantly reduced.

Design Configuration E

This design is identical to Design Configuration D except in the method of attachment of the flexible laminate to the rigid base.

The "ears" of the heat seal are extended through the bottom of the base, through two parallel slits in the base. This attaches the pouch to the base forming a stable "bowl" for convenient consumption, but allows the pouch enough freedom to prevent distortion of the base upon vacuum packing. The total package is very easily constructed and filled.

The package maintains its dimensional characteristics for stowage. The points of potential failure have been reduced to a minimum to produce a highly reliable package. The package is easily compatible with the heating oven and the serving tray. The package is opened with one easily effected cut through the flexible material.

1.3.3 Design Selection (cont'd)

After consumption, the flexible portion folds down to effect a reclosure for bacteriostases and waste disposal. Design Configuration E is considered to be the best design option of the five alternatives studied.

1.3.4 Fluid Seal

The parameters of the fluid seal were specified in the initial System Design Study. In that phase it was determined that a needle and septum design would be optimum. In this follow on phase, the needle and septum design was studied in sufficient detail to conclude that the design is functional within the requirements.

1.3.4.1 Materials

Silicone RTV rubber was selected for the fluid seal material to be used in this design. This material is a fluid adhesive which sets up as a flexible solid when exposed to air. Its advantage in this application is that it will adhere directly to the surface of the package regardless of any irregularities in the surface. It is inexpensive, readily available, and can be applied accurately by a machine. Many forms of RTV silicone rubber are approved for direct contact with food. The material continues to form an air-tight seal regardless of the number of times it has been punctured without loss of functionality.

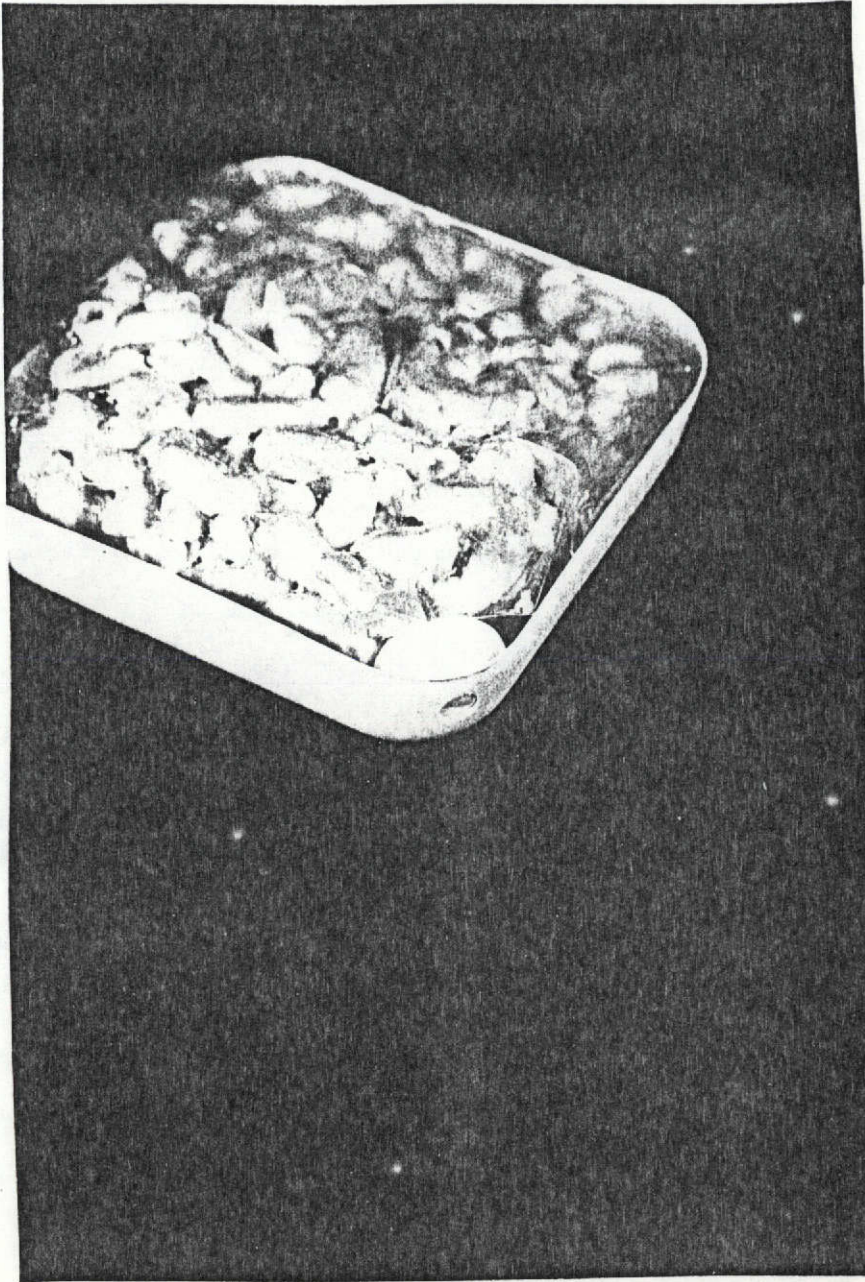
The material of choice for the needle is stainless steel.

1.3.4.2 Fluid Seal Location

Several locations for the fluid seal were tested. Because it was considered easier to insert the needle in the corner, and for reasons of manufacturing efficiencies, the corner location was chosen for this design configuration. The material is applied after the package is sealed by depositing an aliquot of RTV rubber in the corner of the package between the flexible laminate and the base, where it flows into contact with both surfaces and effects a seal. The option seal locations are illustrated in Figures 11 and 12.

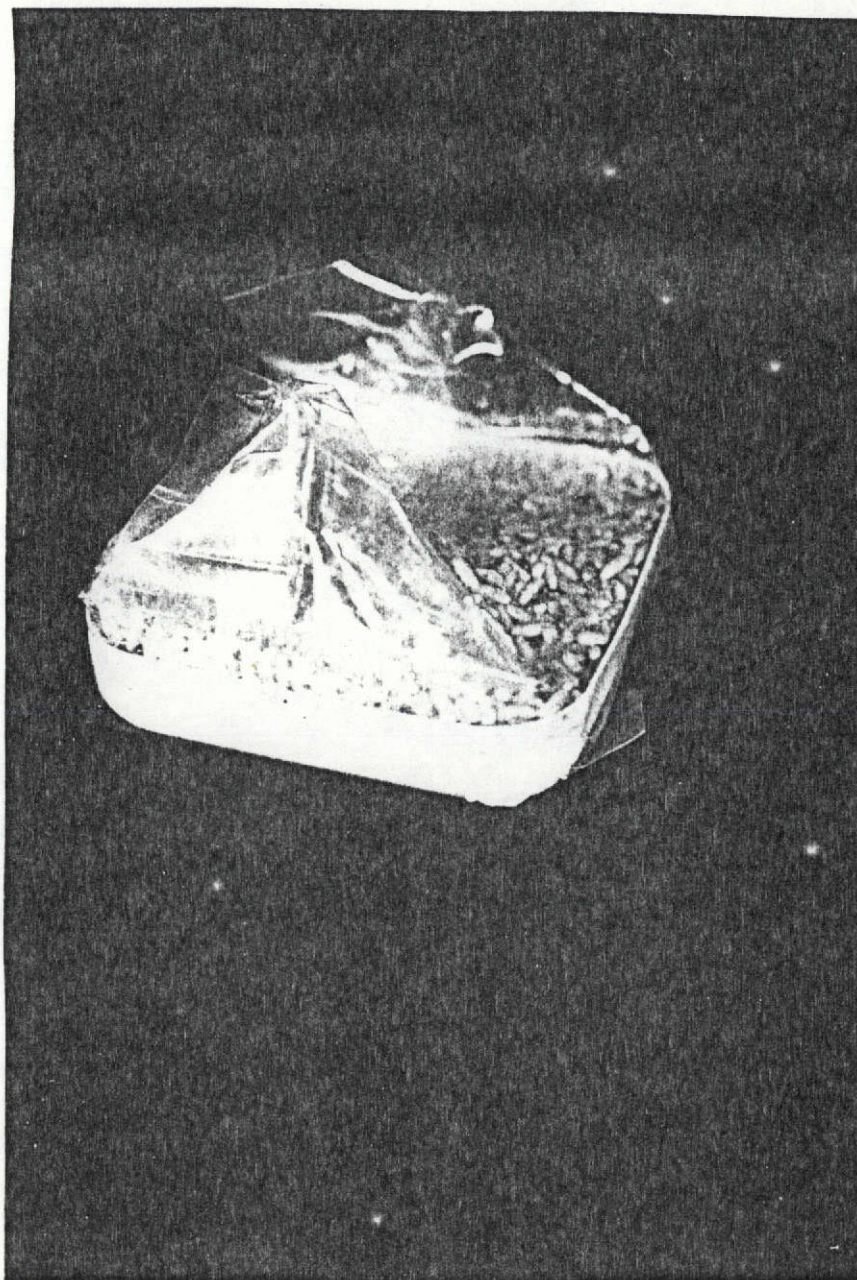
1.3.4.3 Needle Design

Several needle designs were tested. It was determined that the water ports should be on the side of the needle to prevent plugging with food or septum material, as happens when the port opens along the axis of the needle. The needle must be sharp to penetrate the various materials with ease. The base of the needle and the diameter of the ports were determined by flow measurement test. Needle diameters from 15 through 18 guage, lengths from 1/2" through 2", and port diameters of 2/64" and 3/64" were tested at water pressure from 8 through 17 psia. It was determined that a 16 guage needle of 1" or shorter, with two 3/64" ports, will produce the required minimum flow rate of 60 pounds per hour at the minimum water pressure of 8 psia. A detail of the needle used is shown in Figure 13. A summary of the flow characteristics of this prototype is presented in Figure 14.



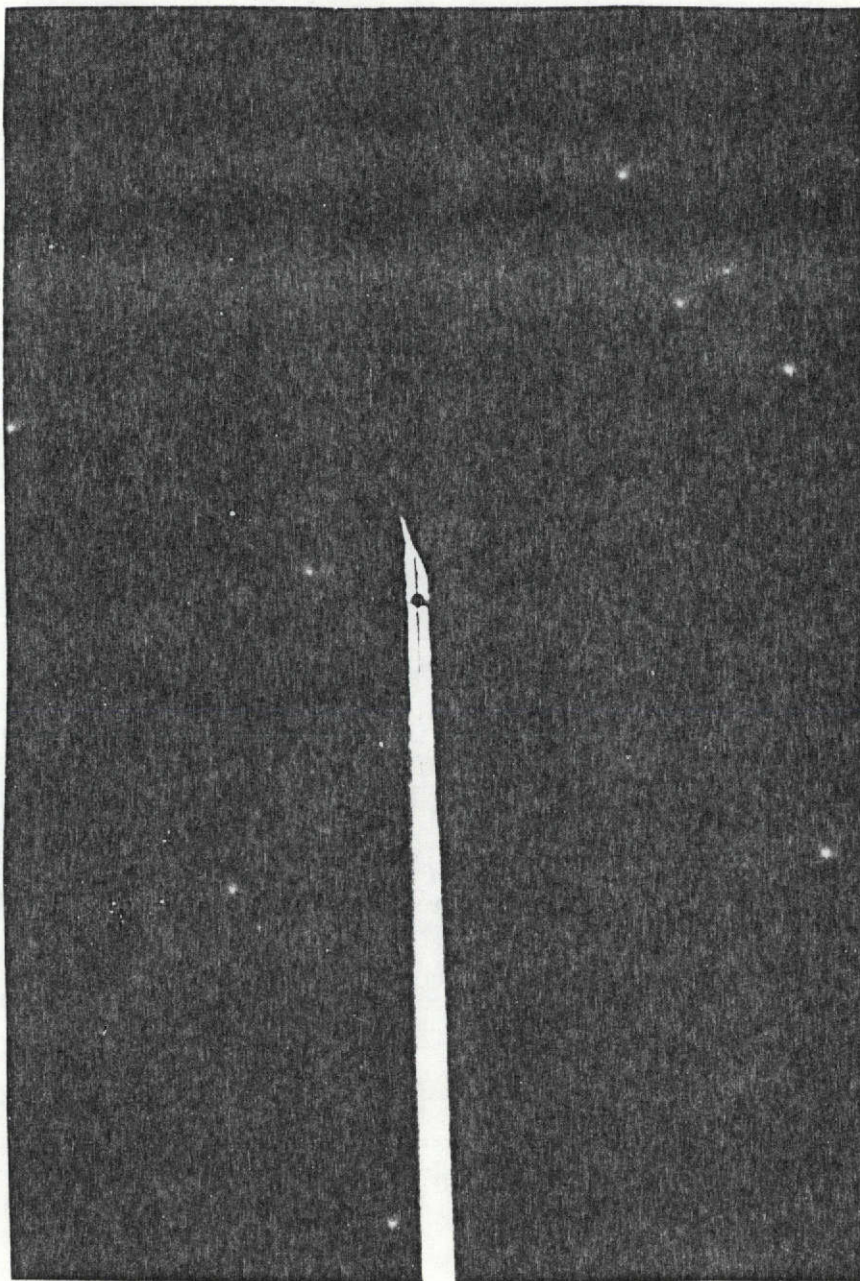
FLUID SEAL LOCATION (OUTSIDE)

FIGURE 11



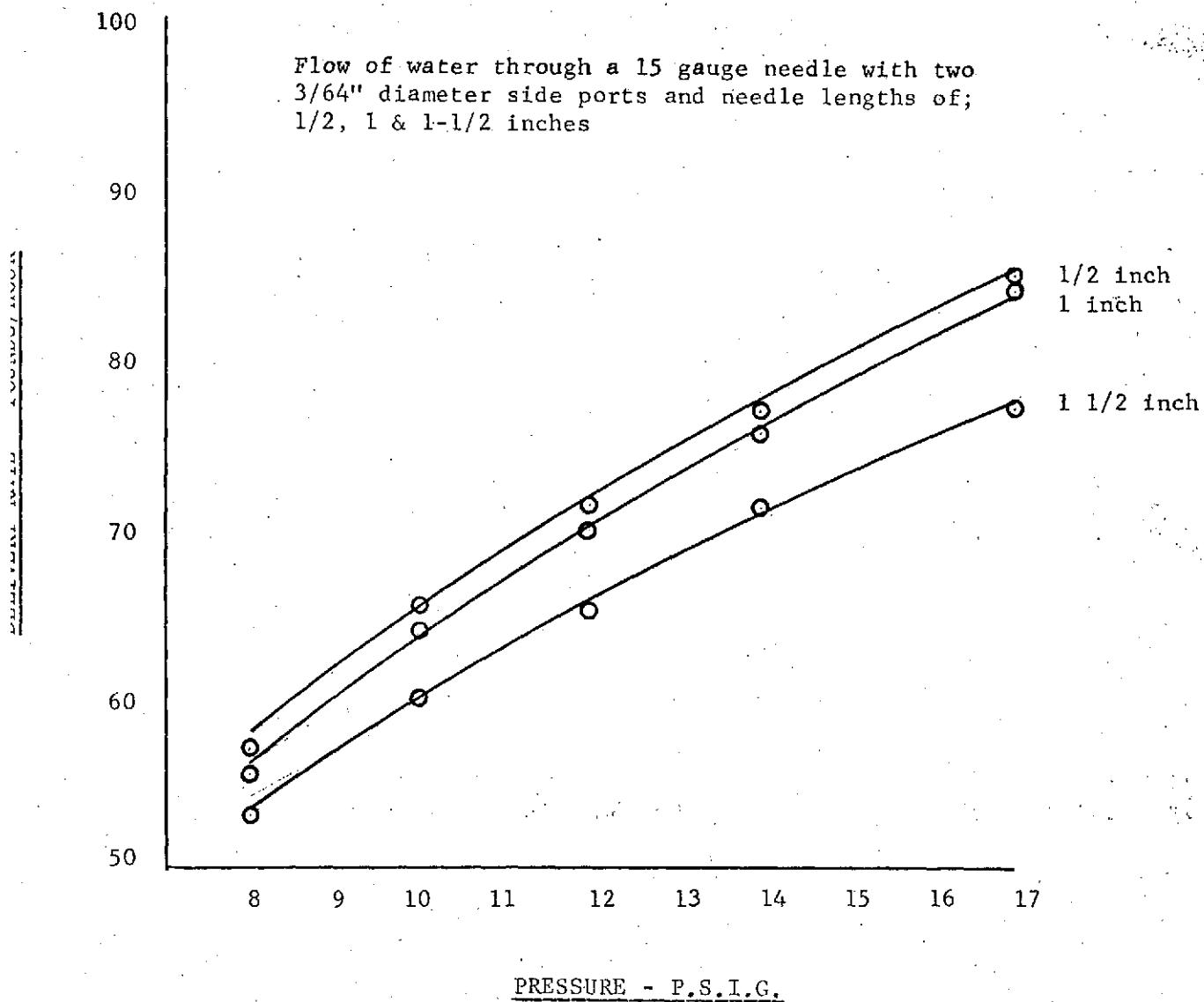
FLUID SEAL LOCATION (INSIDE)

FIGURE 12



REHYDRATION NEEDLE DETAIL

FIGURE 13



REHYDRATION FLOW CHARACTERISTICS

FIGURE 14

1.3.4.4 Rehydration

Several problems with past experiences in feeding of rehydratable foods in space have been identified. Rehydration phenomena occurring in the package configuration chosen were studied in sufficient depth to confirm that the problems as known will be accounted for.

- a) air and/or water leakage past the fluid seal
- b) insufficient pressure differential between the package interior and the environment
- c) gases entrained in the rehydration water
- d) heat expansion of package gases.

As a result of this study it was concluded that a package vacuum is essential to complete rehydration. It was determined that an internal package pressure 1/15th of the atmospheric pressure in the cabin is necessary to ensure complete rehydration of the food items with no dry, unrehydrated areas. When the rehydration takes place with no gases entrained in the rehydration water, rehydration is complete and the package has the identical size and shape as before rehydration. In contrast to the mechanical spring-loaded valve, the needle and septum design ensures such a rehydration. It was determined that entrained gases up to 5% by volume at 15 psia and 160°F. can be tolerated without loss of functionality.

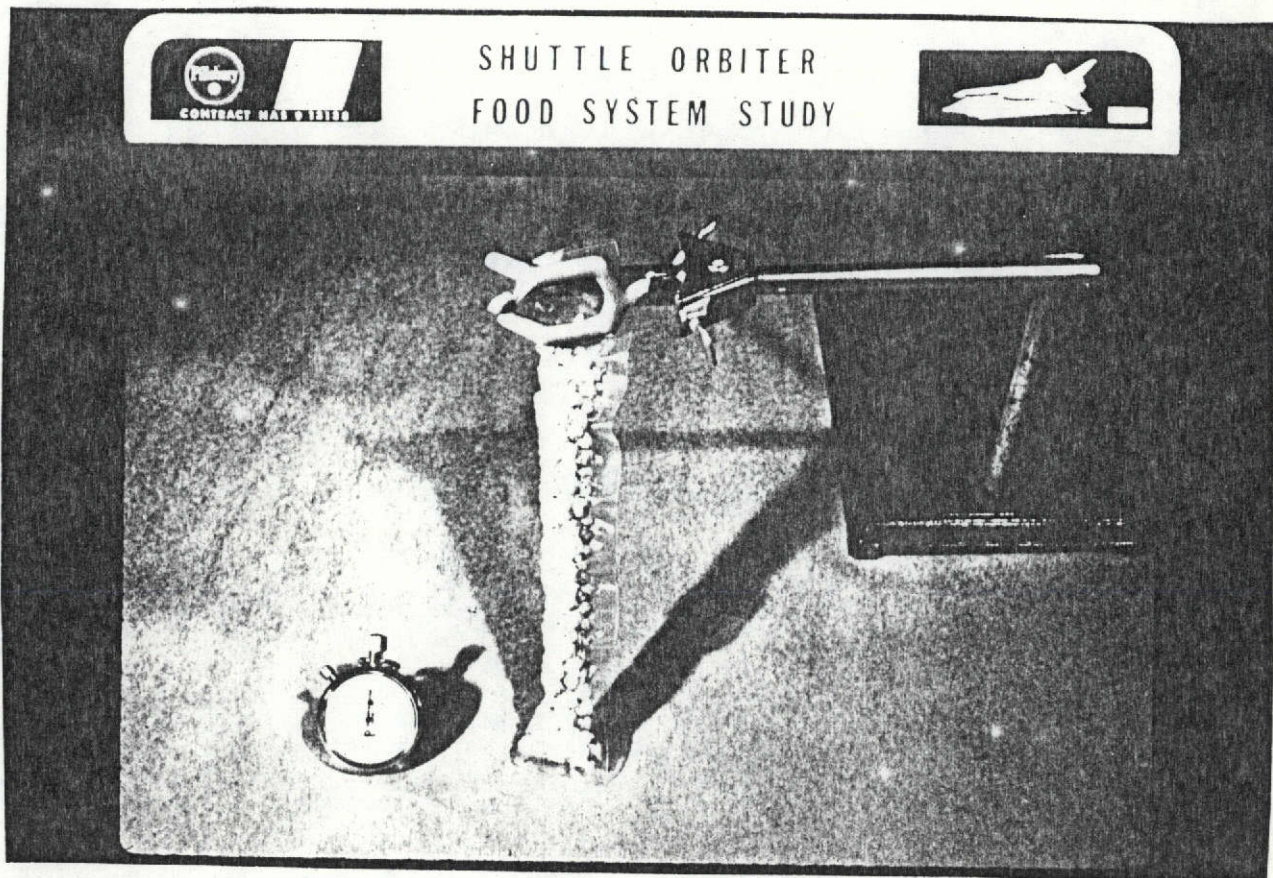
In contrast to the situation with Skylab where a package pressure of 1/3 psia would be required to equal 1/15th of the cabin pressure of 5 psia, the required 1 psia (1/15th x 15 psia) internal pressure for shuttle packaging is within the state-of-art capabilities of packaging equipment.

1.3.4.4 Rehydration (cont'd)

All of the heat energy required to bring the rehydratable food to 149°F. is introduced with the rehydration water. Any gases entrapped within the package will experience no further heating. This will minimize the volume expansion of the package due to heat expansion of contained gases.

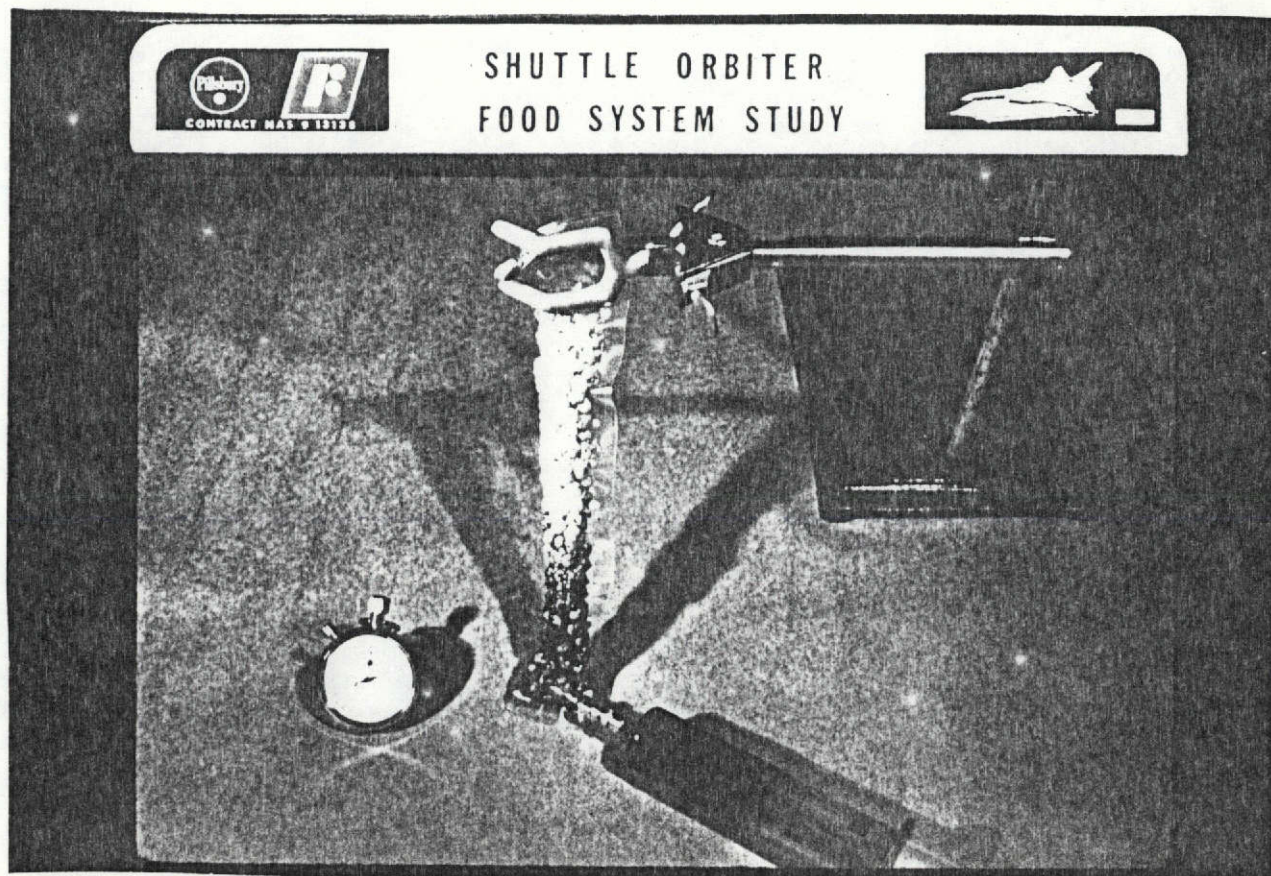
The principles involved in effecting a complete rehydration of freeze-dried items with no kneading and no volume expansion of the package are illustrated in the accompanying time-series photographs, Figures 15 through 22.

These figures illustrate the self-rehydration of a dry product packaged in a flexible pouch at an internal pressure of 1 psia. Rehydration takes place through an RTV septum with a hypodermic syringe and needle. Figure 15 shows the package set up in its original position prior to insertion of the rehydration needle. Figure 16 shows the needle inserted through the RTV septum at 5 1/2 seconds of rehydration time. After insertion of the needle through the septum, no pressure whatever was exerted on the hypodermic plunger. Water was drawn into the package solely as a result of the pressure differential. As the water front passed through the package, the water flowed throughout the food pieces, reentering the internal voids in the food. As long as air is prevented from entering the package, this process is uninhibited.



REHYDRATION STUDY SET UP TIME ZERO

FIGURE 15



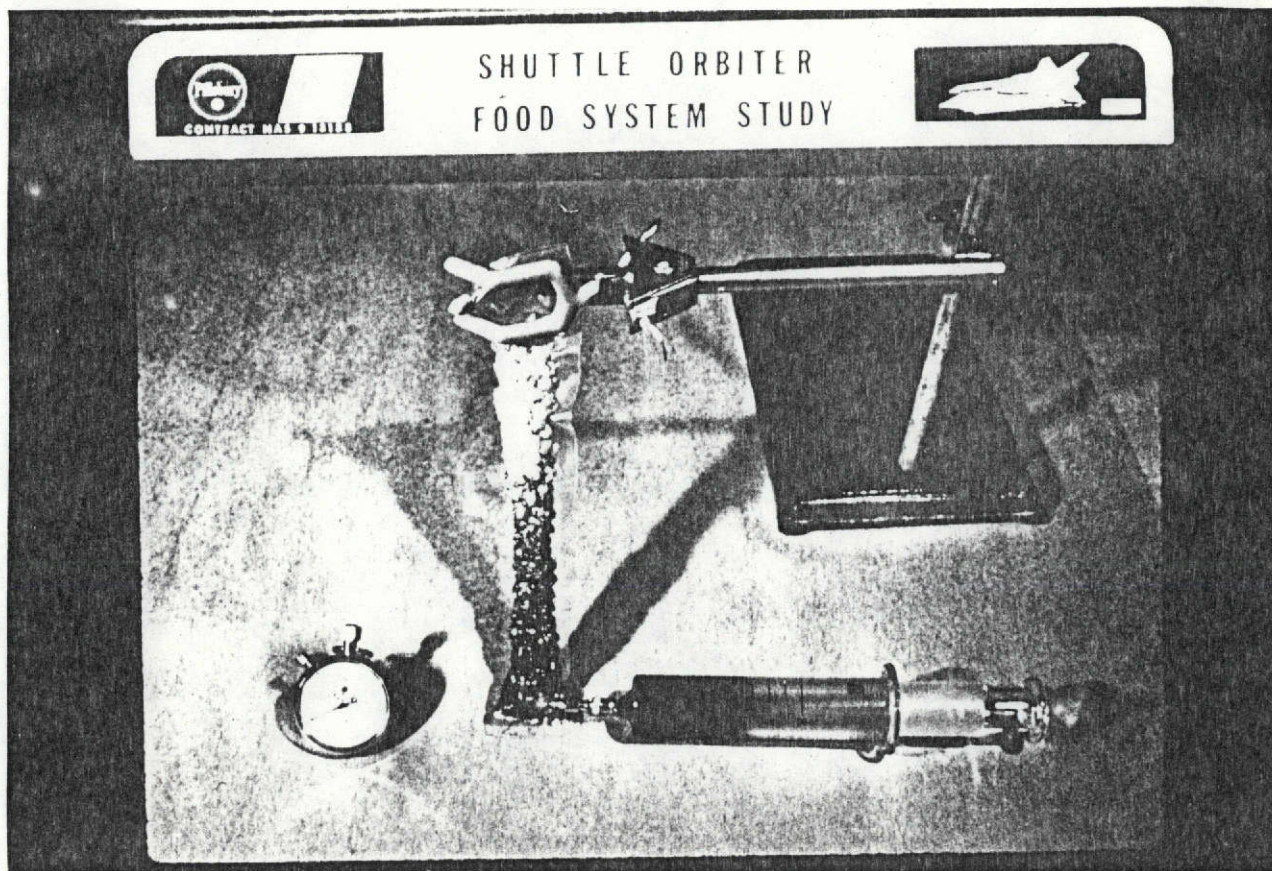
REHYDRATION STUDY SET UP TIME 5 1/2 SECONDS

FIGURE 16

1.3.4.4 Rehydration (cont'd)

The syringe initially held 50 mls. Figure 17 shows the package approximately 60 percent filled at 15 seconds of rehydration time. Figure 18 shows the package approximately 70 percent filled after 20 seconds of rehydration time. Figure 19 shows the package approximately 80 percent filled after 30 seconds of rehydration time. Figure 20 shows the package approximately 90 percent filled after 50 seconds. After 78 seconds, the water front had reached the top of the package, and had entered the folds in the laminate above the food as shown in Figure 21. At this point 36 mls had been taken into the package. During the next 72 seconds, an additional 6 mls. of water uptake was observed. This uptake was the result of absorption of moisture by the dry material. The total uptake was 42 mls. as illustrated in Figure 22.

These photographs illustrate that total rehydration can be achieved under easily specified conditions. This process was used to successfully rehydrate solid meat chunks up to 1" x 1" x 6" in size. Little or no kneading is required to insure complete penetration to all areas of the food. The final rehydration package is identical in size and shape with the package before rehydration.

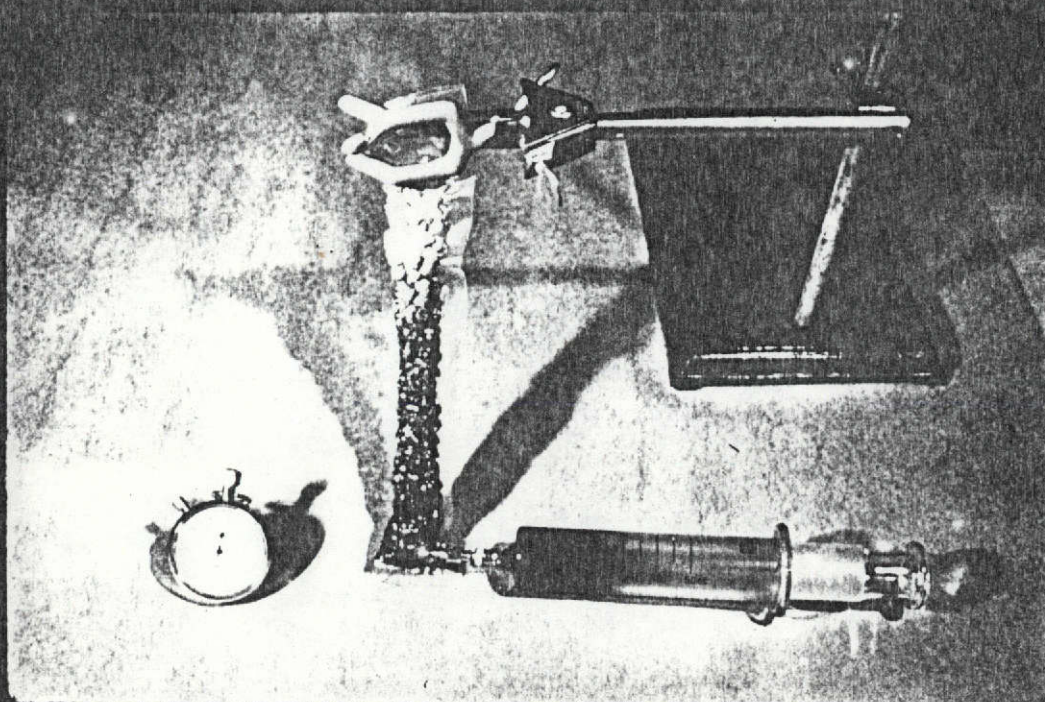


REHYDRATION STUDY SET UP TIME 15 SECONDS

FIGURE 17

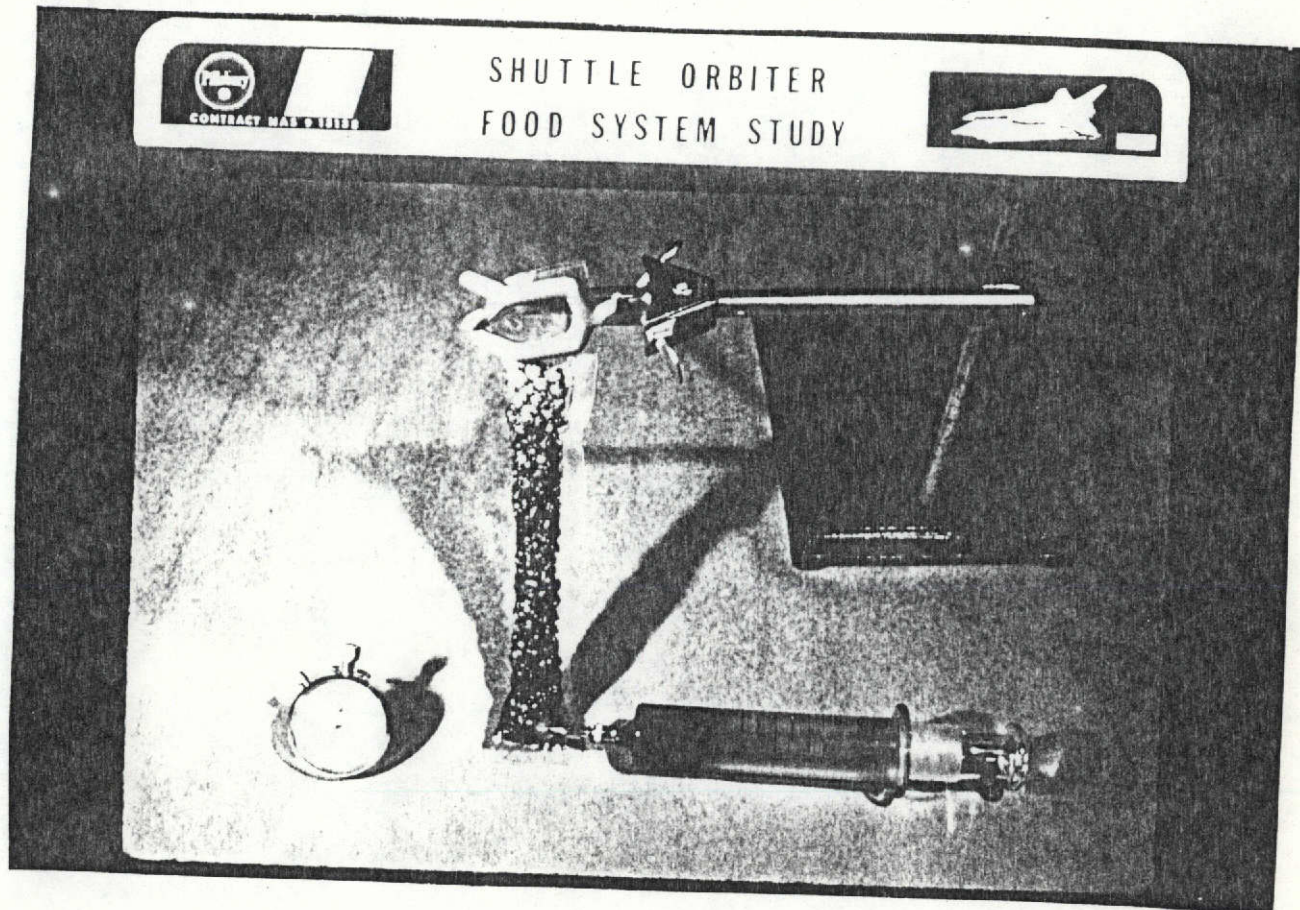


SHUTTLE ORBITER
FOOD SYSTEM STUDY



REHYDRATION STUDY SET UP TIME 20 SECONDS

FIGURE 18

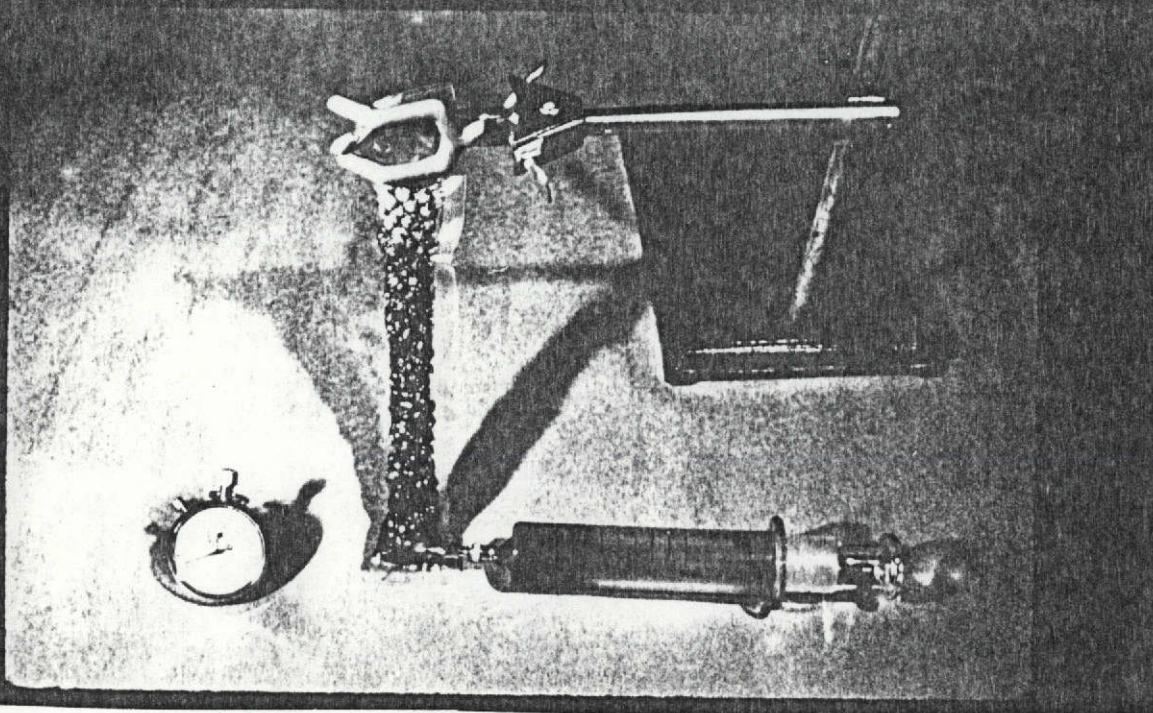


REHYDRATION STUDY SET UP TIME 30 SECONDS

FIGURE 19



SHUTTLE ORBITER FOOD SYSTEM STUDY

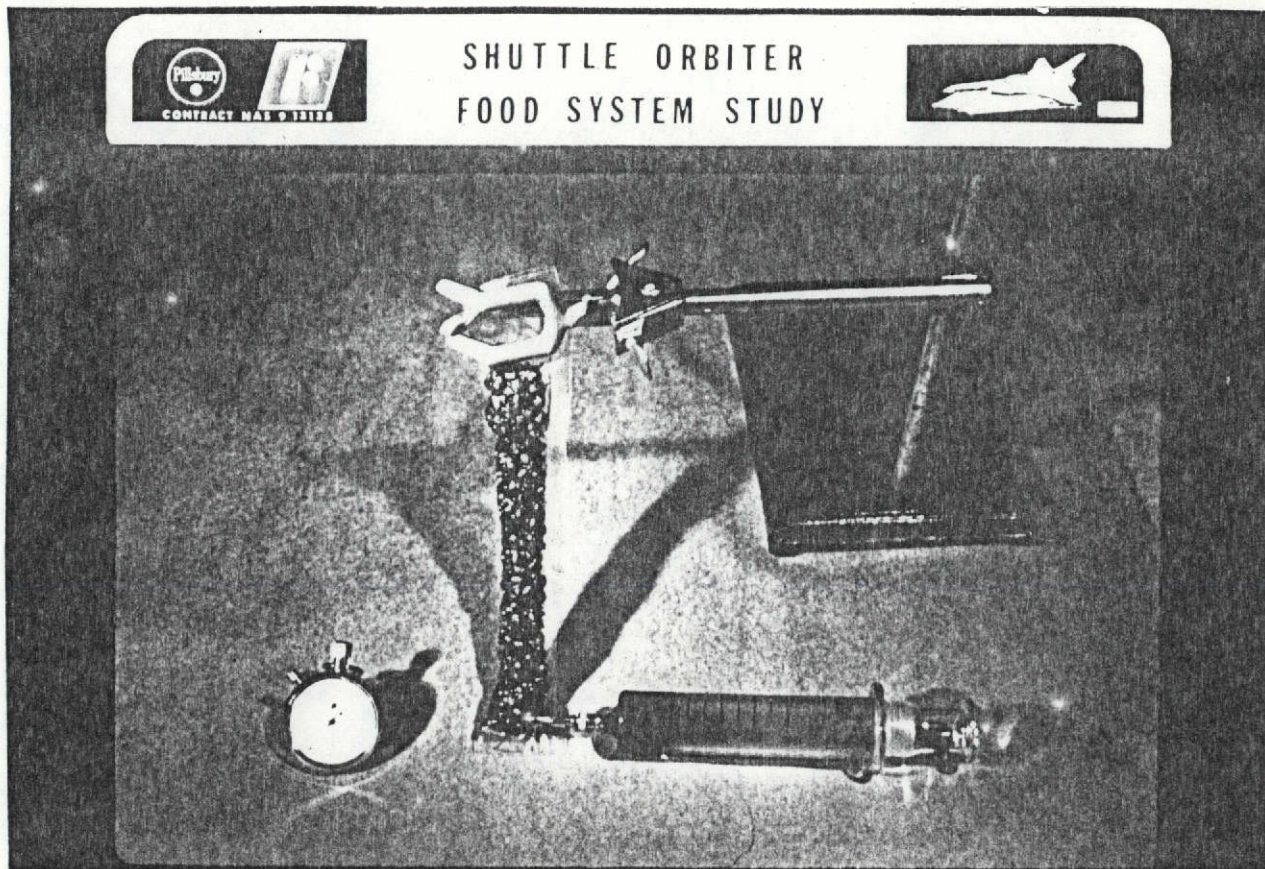


REHYDRATION STUDY SET UP TIME 50 SECONDS

FIGURE 20



SHUTTLE ORBITER FOOD SYSTEM STUDY

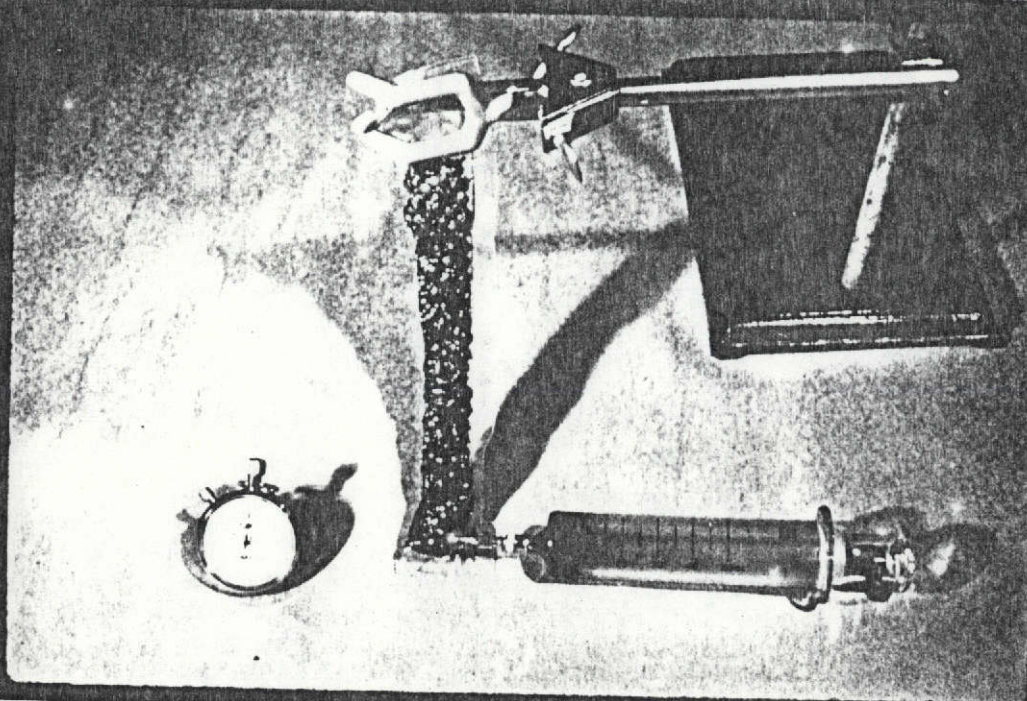


78 SECONDS

FIGURE 21



SHUTTLE ORBITER FOOD SYSTEM STUDY



COMPLETE REHYDRATION 150 SECONDS

FIGURE 22

1.4 Drink Package Concept

To be compatible with the galley water delivery system, the drink package should incorporate a septum similar to that of the rehydratable package. The air-tight mating of the seal to the needle will prevent entrance of air during filling, preventing beverages from foaming.

To fulfill requirements of weight and stowage, the drink package should be a flexible pouch of laminate material.

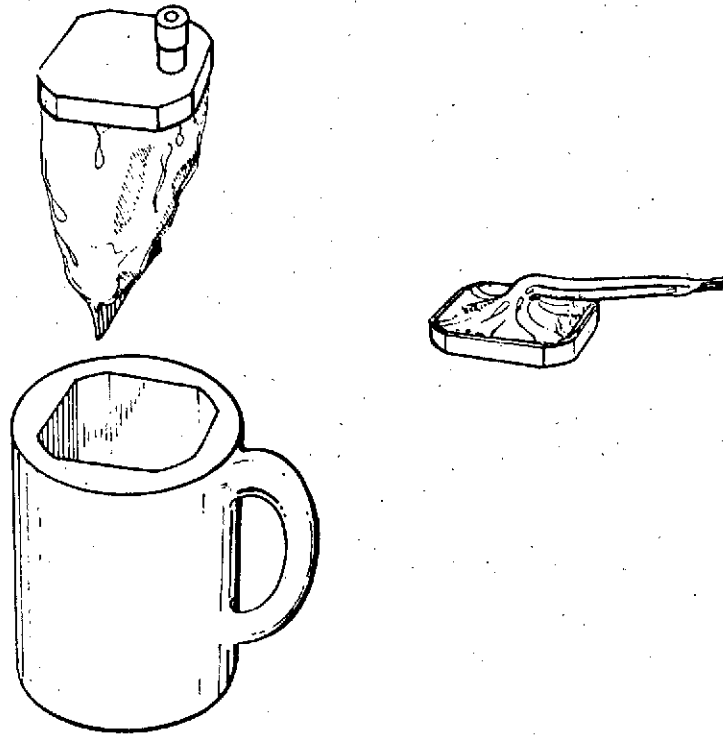
Many of the beverages will be hot type, and flexible packaging provides little insulation value. This hampers handling, and hastens cooling of the beverage. A primary package which provides the necessary insulation qualities will add unnecessarily to the bulk and weight of the package. The concept, therefore, should provide a reusable sleeve which can be of a highly insulative material, and which will contain the primary drink package.

The use of a septum will require a "straw" for insertion through the septum to allow withdrawal of the liquid. This straw can be either reusable or disposable. It should provide a positive closure to prevent expulsion of liquid into the cabin, until the user actuates the bite valve.

1.4 Drink Package Concept (cont'd)

The containers should consist of two parts. A flexible pouch which expands on filling to contain the beverage, and subsequently collapses on withdrawal; and a rigid top which supports the septum and provides the rigidity necessary for mating the primary package to the reusable sleeve. The primary package can be constructed very similarly to the rehydratable package.

The concept, with the insulative sleeve fashioned in the shape of a cup for familiarity is shown in Figure 23.



DRINK CUP CONCEPT

FIGURE 23